# Booster Trim Magnet

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Magnet parameters shown in the Table 1.

Table 1

| Type | Integrated field/gradient | Effective length | Aperture field/gradient | Field at 1" radius |
|---|---|---|---|---|
| Horizontal dipole | 0.009 T-m | 0.2 m | 0.045 T | 0.045 T |
| Vertical dipole | 0.015 T-m | 0.2 m | 0.075 T | 0.075 T |
| Normal quadrupole | 0.08 T-m/m | 0.2 m | 0.4 T/m | 0.01016 T |
| Skew quadrupole | 0.0024 T-m/m | 0.2 m | 0.012 T/m | 0.0003 T |

## Version 1

The shell type coils placed around the beam pipe generate the magnetic field. This approach was used in the old magnet design. To increase the magnet strength needed more effective cooling. Using cooling fins in this geometry is rather complicated because of coils overlapping and eddy current losses in cooling fins.

One of the way to solve these problems is to use water cooled multiwire cable shown in Fig. 1.

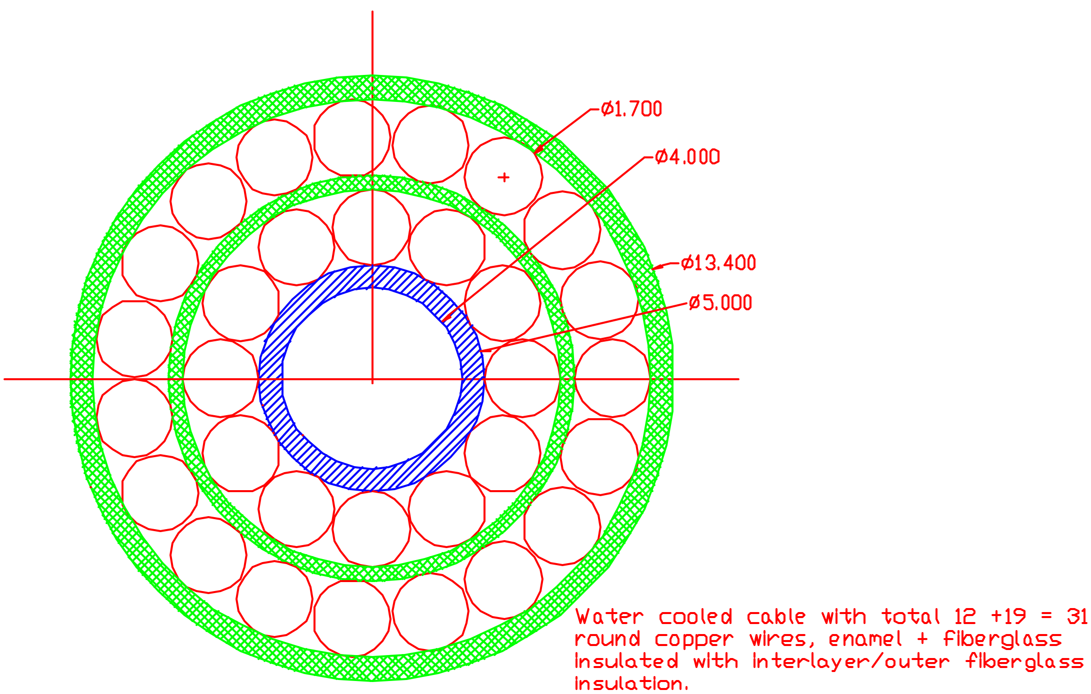


Fig. 1. Multiwire cable cross-section

The shell type magnet configuration is shown in Fig. 2.

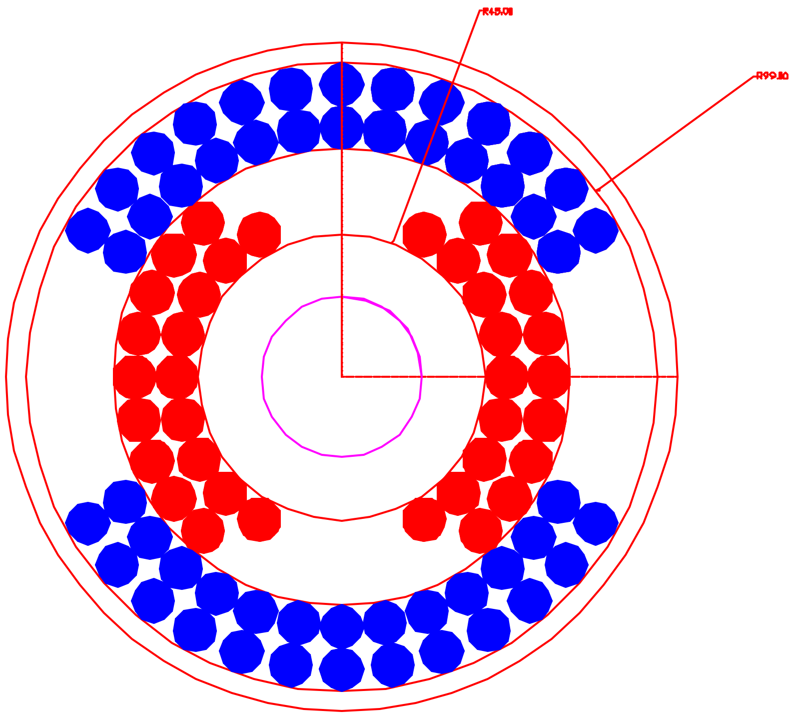

Fig. 2. Trim magnet with two dipole windings.

The cable consists of the inner copper pipe and two layers of 1.5 mm diameter round copper wires wound around this pipe. Each wire has enamel and fiberglass insulation. Group or one wire connected in series form the dipole or quadrupole coil.

Because of good cooling the magnet current density can be increased and coil temperature will have a good control. The average current density 4 A/mm$^2$ (maximum 8 A/mm$^2$) was chosen. The wire maximum current will be 15 A. The coil voltage can be reduced if connect several wires in parallel.

The samples of this cable can be made using IB3 cabling and insulating machines. Round cable without pipe was manufactured for Fast Phase Shifter Solenoid. All coil assembly should be vacuum impregnated with epoxy.

Because the outer ferromagnetic return yoke in this design rather far away the magnet efficiency close to the air core magnet.

## Version 2

Another option is to form the magnetic field by ferromagnetic poles. In this case the winding ampere-turns will be essentially reduced. Racetrack type coils simplify the manufacturing process (see Fig. 3.).

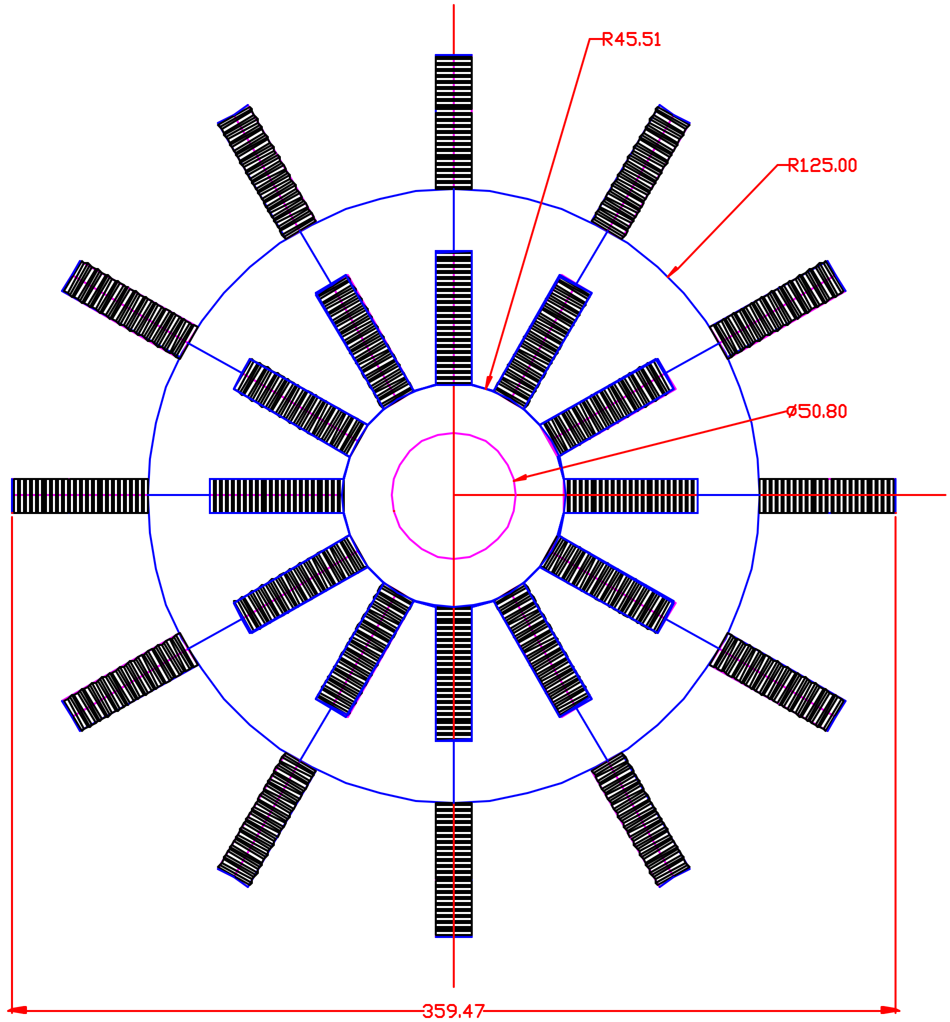


Fig. 3 Trim with racetrack type coils

The coils are wound from flat copper conductor with bare dimensions 12 mm x 1 mm. The enamel, turn-to-turn and ground insulation will increase these dimensions to 14.5 mm x 1.2 mm. Cooling pipes inside the iron poles and cooling fins for return conductors can effectively cool the flat coil and cable from both sides. The yoke are assembled from 0.35-0.5 mm transformer type steel. The coils wound into the yoke slots with preliminary placed ground insulation. One slot has maximum 4 sections each of them should be connected in series with corresponding sections to for dipole or quadrupole winding.

The preliminary field quality analysis shown on Fig. 4 – 7.

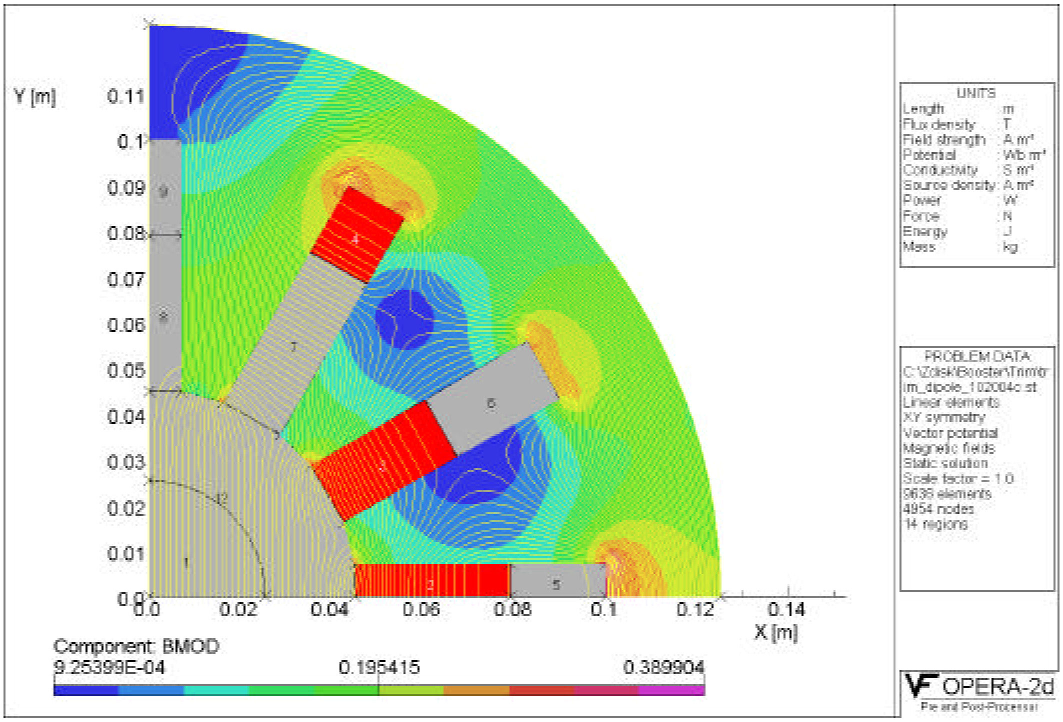

Fig. 4. Dipole field 0.082 T and flux density distribution in the yoke

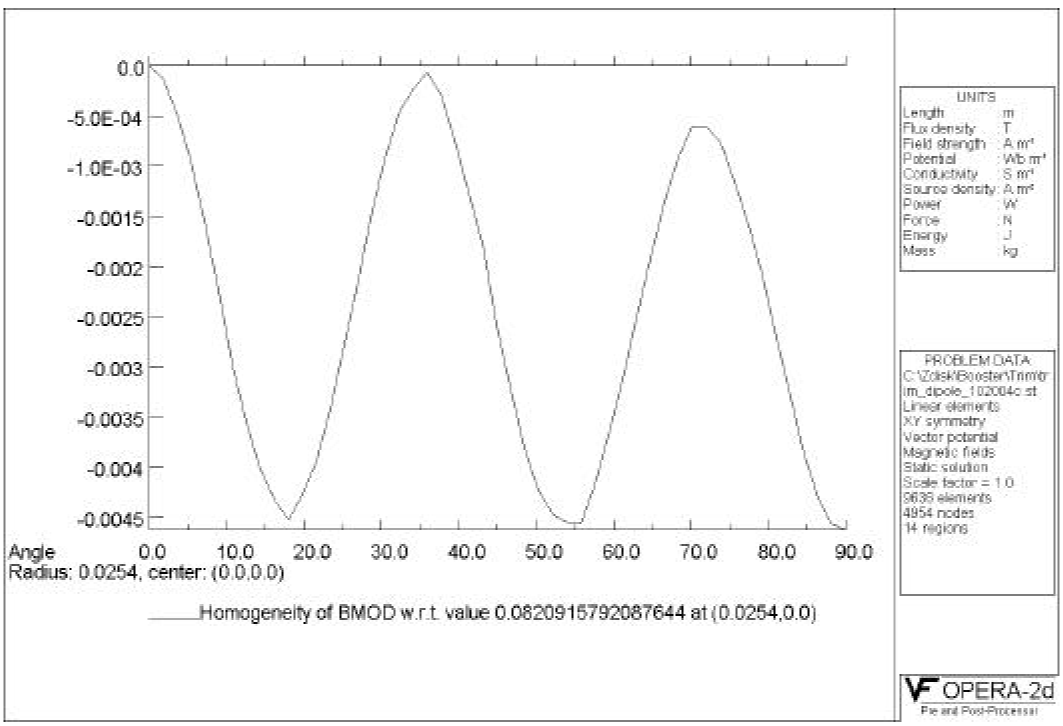

Fig. 5. Dipole field homogeneity at reference radius 1 " (25.4 mm).

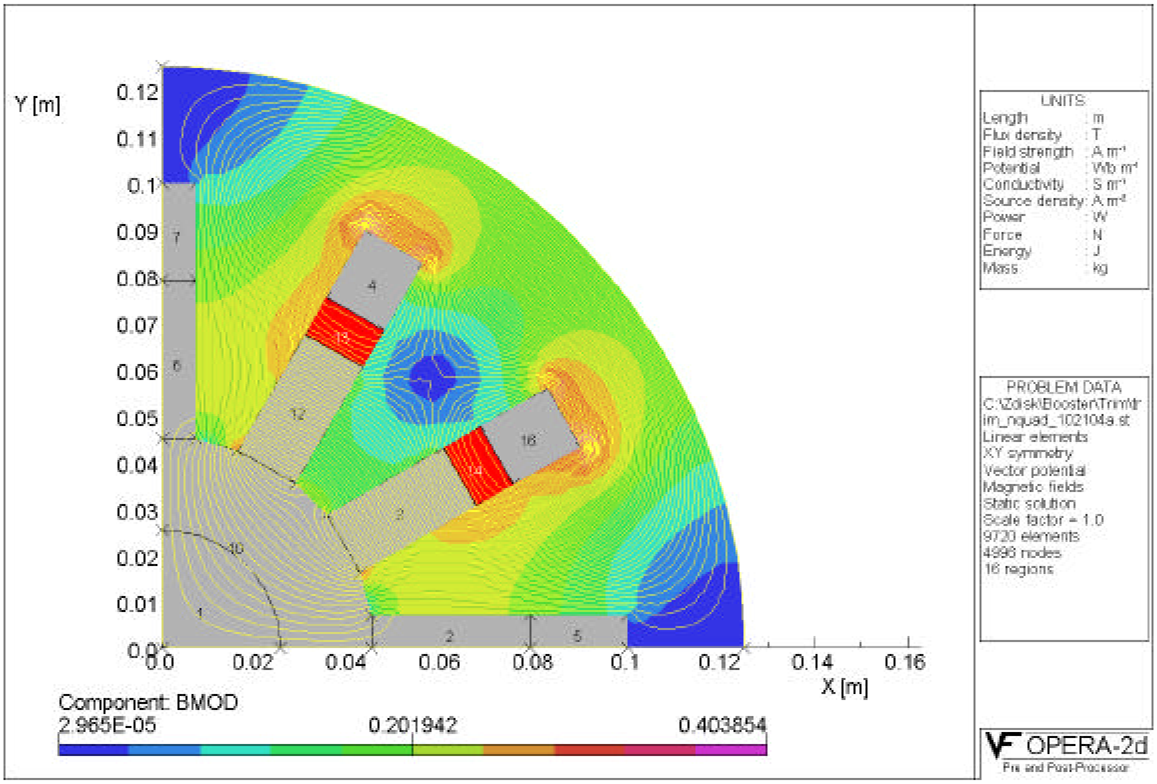


Fig. 6. Skew quadrupole field and flux density distribution in the yoke

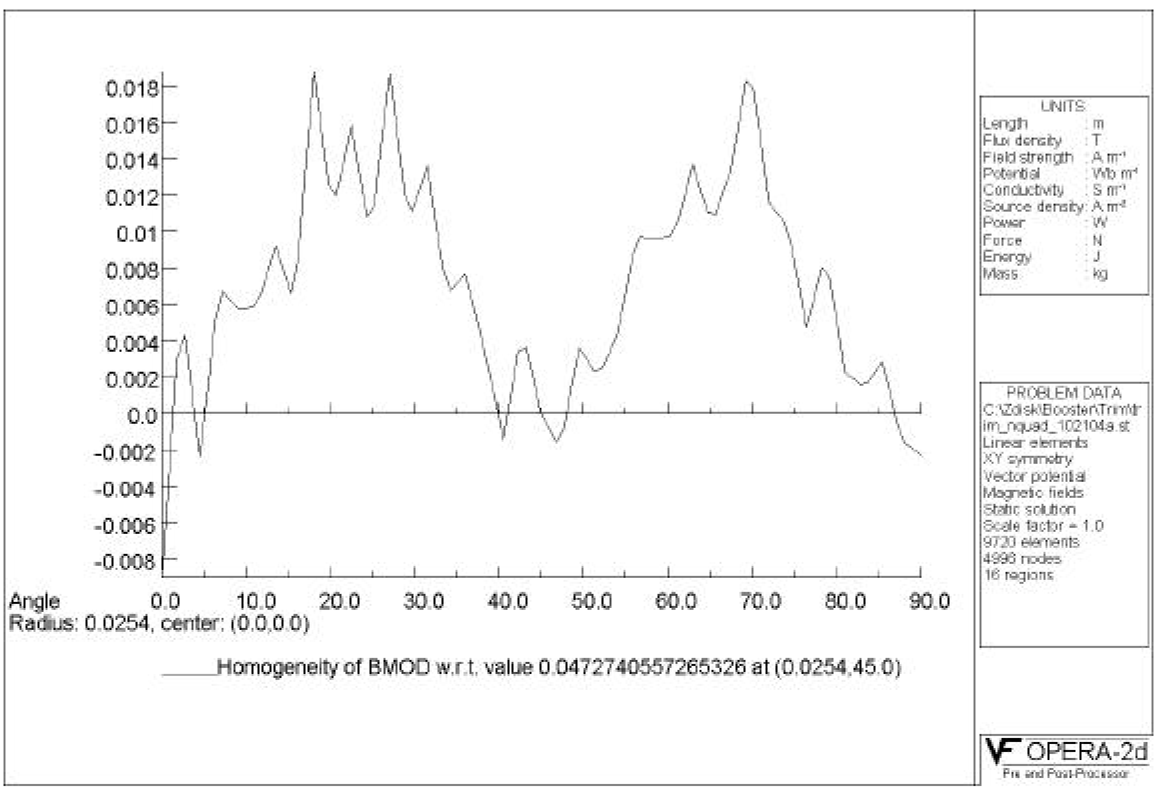


Fig. 7. Quadrupole field homogeneity at reference radius 1 “ (25.4 mm).

# Summary

Two versions of trim magnet are under consideration. Both of them are visible.

The shell type coils have compact design, better cooling, can form high quality of magnetic field. At the same time needs more ampere-turns, more tooling and special cable.

The second version will be less expensive and simpler for manufacturing. Nevertheless the careful analysis should be made for heat transfer conditions at maximum currents.